DØnote 5195-CONF

Search for Randall-Sundrum Gravitons in Dilepton and Diphoton Final States with 1 fb^{-1} of Data

The DØ Collaboration
URL http://www-d0.fnal.gov

(Dated: July 25, 2006)

We report a preliminary result from a search for Randall-Sundrum gravitons decaying to dielectron and diphoton final states in 1 fb^{-1} of data collected by the DØ detector at Fermilab. The Randall-Sundrum model has two parameters that can be expressed in terms of the mass of the first excited graviton mode M_1 and the dimensionless coupling to standard model fields $k\sqrt{8\pi}/M_{Planck}$. We do not find any excess over standard model expectations and exclude $M_1 < 865(240)$ GeV at 95% confidence level for $k\sqrt{8\pi}/M_{Planck} = 0.1(0.01)$.

I. INTRODUCTION

Models postulating the existence of extra spatial dimensions have been proposed to solve the hierarchy problem posed by the large difference between the Planck scale $M_{Planck} \approx 10^{16}$ TeV, at which gravity is expected to become strong, and the scale of electroweak symmetry breaking, ≈ 1 TeV.

One such model by Randall and Sundrum[1] localizes gravity on a (3+1)-dimensional brane, the Planck brane, that is separated from the standard model brane in a 5^{th} dimension with warped metric. In the simplest version of this model gravitons are the only particles that can propagate in the extra dimension. Due to the warped metric their wave functions are exponentially suppressed away from the Planck brane and thus gravity appears weak at the standard model brane. The gravitons appear as towers of Kaluza-Klein excitations with masses and widths determined by the parameters of the model. These parameters can be expressed in terms of the mass of the first excited mode of the graviton, M_1 and the dimensionless coupling to the standard model fields $k\sqrt{8\pi}/M_{Planck}$. The coupling is constrained to lie between about 0.01 and 0.1 by the requirements that predictions be consistent with precision electroweak data and that the model remains perturbative.

If it is light enough, the first excited graviton mode could be resonantly produced at the Tevatron. It is expected to decay to fermion-antifermion and to diboson pairs. Due to the graviton having spin 2 the branching fraction to diphoton final states is expected to be twice that to e^+e^- final states.

This analysis uses about 1 fb^{-1} of data taken by the DØ detector at the Fermilab Tevatron between October 2002 and February 2006. The Tevatron collides protons and antiprotons at a center of mass energy of 1.96 TeV. This increases the amount of integrated luminosity analyzed by a factor of four over the previous search in this channel by DØ[2].

II. EVENT SELECTION

The DØ detector is a typical multipurpose collider detector, that consists of central tracking, calorimeter, and muon detection systems [3] [4].

We select events that have two isolated clusters of energy depositions in the central electromagnetic calorimeter ($|\eta| < 1.1$) with transverse momentum $p_T > 25$ GeV. We require that the energy deposition patterns are consistent with electromagnetic showers. In order to accept both $\gamma\gamma$ and ee decay channels no track match was required for the objects. We find 50354 such events with an invariant mass of the two electromagntic showers above 50 GeV.

These events were acquired using triggers requiring one or two electromagnetic objects. Sufficiently far above their p_T thresholds these triggers are close to 100% efficient for electrons and photons that pass our selection cuts.

We use Monte Carlo to calculate the acceptance of our detector for events with e^+e^- and $\gamma\gamma$ final states.

We measure the efficiency for electrons to pass isolation and energy profile cuts to be 93% using collider data from $Z \to ee$ and 96% determined from $Z \to ee$ Monte Carlo. For the graviton signal efficiency we use the efficiency from the Monte Carlo, corrected for the ratio of efficiencies from data and Monte Carlo for electrons.

III. BACKGROUND ESTIMATION

We distinguish between physics backgrounds with genuine e^+e^- and $\gamma\gamma$ final states and instrumental backgrounds in which one or both of the electromagnetic objects are misidentified.

The sources of physics backgrounds are Drell-Yan production of e^+e^- and direct $\gamma\gamma$ production. We estimate these contributions using a Monte Carlo simulation. We use PYTHIA[5] to generate the events and the standard DØ detector simulation using GEANT3[6]. In order to predict the shape of the invariant mass spectrum from the physics backgrounds we combine the spectra from DY and $\gamma\gamma$ MC samples according to their cross sections multiplied with the respective acceptance$\times$efficiency for e^+e^- and $\gamma\gamma$ final states.

We estimate instrumental backgrounds from a collider data sample containing two electromagnetic objects selected to be inconsistent with electromagnetic showers. These data provide us with an estimate of the shape of the invariant mass spectrum of events with misidentified electrons and photons. In order to determine the number of instrumental background events, we fit the invariant mass spectrum observed in collider data around the Z peak in the interval $60 < m(ee) < 140$ GeV with a superposition of the physics background shape and the instrumental background shape to determine the relative contributions from the two sources. Figure 1 shows the invariant mass spectra for data and the fitted background composition superimposed.

We predict the shape of the expected invariant mass spectrum above 140 GeV using the background estimates and compare to collider data. Figure 2 shows the full mass spectra for data, the total background and the instrumental background contributions.

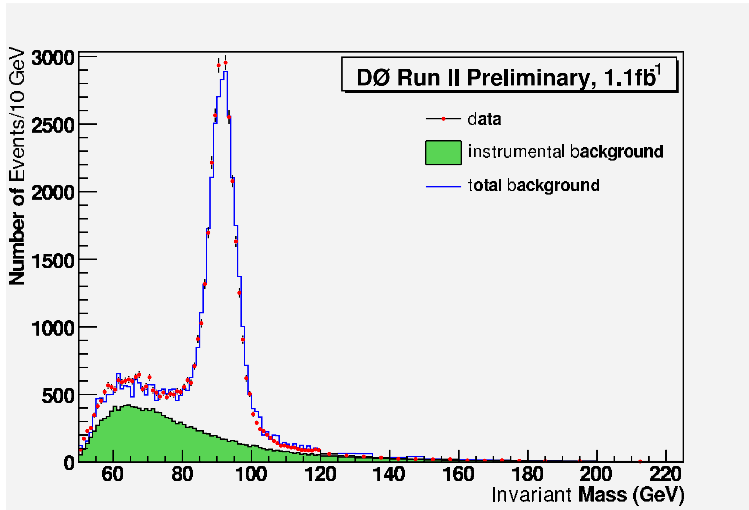

FIG. 1: Invariant mass spectra from data (points) with the fitted total background shape (open histogram) and contribution from instrumental backgrounds (shaded histogram) superimposed.

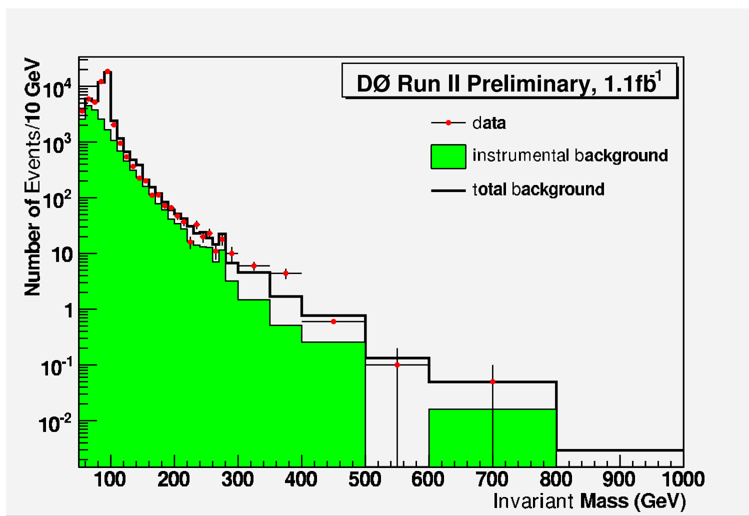

FIG. 2: Invariant mass spectra from collider data (points) with expected total background (open histogram) and instrumental background (shaded histogram) superimposed.

IV. LIMIT CALCULATION

We extract the integrated luminosity of our data sample from the scale factor for the DY spectrum determined in section III. We take the LO cross section for DY and diphoton production and a mass independent k-factor of 1.34[7] to determine an integrated luminosity of 1.1 fb^{-1}.

We test for the presence of a graviton decay signal using a sliding mass window that was chosen to optimize sensitivity to a range of hypothesized values of graviton masses. Table I summarizes the systematic uncertainties. Mass windows and systematic uncertainties were taken from the published analysis of a smaller data set[2].

We use a Bayesian approach[8] with a flat prior to calculate an upper limit on the cross section $\sigma(p\overline{p} \to G + X)$ times branching fraction $B(G \to e^+e^-)$. Systematic uncertainties on input parameters are represented by Gaussian priors for these parameters.

Since we accept e^+e^- and $\gamma\gamma$ final states we multiply our integrated luminosity by a factor three.

The results of the limit calculation using a confidence level of 95% are listed in Table II. Figure 3 shows the 95% confidence level upper limit on $\sigma(p\overline{p} \to G + X) \times B(G \to e^+e^-)$ versus the graviton mass compared to the theoretical prediction for cross section times branching fraction for several values of the coupling parameter. Here we use the LO cross section obtained with PYTHIA[5], multiplied by a k-factor of 1.34[7]. To obtain predictions for different

	source	uncertainty
signal	mass dependence of efficiency	5%
	acceptance calculation	5%
	difference between photon and electron efficiency	5%
	Z cross section	4%
total signal uncertainty		9%
background	K factor mass dependence	5%
	efficiency determination	7%
	parton distribution functions	5%
total background uncertainty		10%

TABLE I: Sources of uncertainty for signal and background.

coupling parameters we scale the cross section by $(\kappa\sqrt{8\pi}/M_{Pl})^{-2}$.

Based on 1.1 fb^{-1} of data, we can thus exclude masses for the first excited graviton mode below 865 GeV at 95% confidence level for $\kappa\sqrt{8\pi}/M_{Pl} = 0.1$ and below 240 GeV for $\kappa\sqrt{8\pi}/M_{Pl} = 0.01$. Figure 4 shows the upper limit on the coupling parameter $\kappa\sqrt{8\pi}/M_{Pl}$ as a function of graviton mass M_1.

M_1 (GeV)	mass window (GeV)	data	background	signal acceptance	theory cross section (fb)	expected limit on σ(fb)	observed limit on σ(fb)	expected limit on $\kappa\sqrt{8\pi}/M_{Pl}$	observed limit on $\kappa\sqrt{8\pi}/M_{Pl}$
200	190-210	113	111.8±12.6	0.138±0.013	10167	78.3	77.8	0.0088	0.0087
210	200-220	84	93.4±11.0	0.143±0.013	8324	64.1	51.4	0.0088	0.0079
220	210-230	53	73.0±9.0	0.148±0.014	6480	53.0	30.1	0.0090	0.0068
230	220-240	49	53.7±6.7	0.153±0.014	5413	41.8	35.5	0.0088	0.0081
240	230-250	53	47.0±6.1	0.159±0.015	4346	37.3	48.0	0.0093	0.011
255	240-270	54	57.5±7.2	0.166±0.015	3257	40.2	36.0	0.011	0.011
275	260-290	29	37.0±5.5	0.177±0.016	2156	30.5	21.4	0.012	0.010
290	270-310	35	36.1±5.3	0.184±0.017	1805	28.7	27.5	0.013	0.012
310	290-330	34	23.8±4.0	0.195±0.018	1306	21.8	37.9	0.013	0.017
330	310-350	23	15.9±3.2	0.205±0.019	998	17.1	28.0	0.013	0.017
350	330-370	17	9.9±1.6	0.215±0.020	732	12.4	23.4	0.013	0.018
375	350-400	22	8.5±1.4	0.227±0.021	526	11.0	32.4	0.015	0.025
400	370-430	12	7.0±1.2	0.238±0.022	389	9.7	16.9	0.016	0.021
430	400-460	4	5.0±1.0	0.251±0.023	285	8.1	7.0	0.017	0.016
465	430-500	5	5.0±1.1	0.267±0.025	188	7.6	7.7	0.020	0.020
500	460-540	3	3.38±0.76	0.283±0.026	123	6.3	5.9	0.023	0.022
550	500-600	1	1.33±0.16	0.345±0.032	72.3	3.8	3.6	0.023	0.022
600	550-650	0	0.78±0.10	0.345±0.032	43.4	3.4	2.7	0.028	0.024
650	590-710	1	0.97±0.34	0.336±0.031	25.6	3.6	3.9	0.037	0.038
700	630-770	1	0.76±0.33	0.328±0.030	15.4	3.6	4.0	0.048	0.050
750	670-830	0	0.27±0.05	0.336±0.031	9.1	3.0	2.8	0.057	0.054
800	710-890	0	0.15±0.03	0.345±0.032	5.4	2.7	2.7	0.071	0.069
850	750-950	0	0.07±0.02	0.341±0.032	3.2	2.7	2.7	0.091	0.089
900	790-1010	0	0.08±0.02	0.338±0.031	1.8	2.7	2.7	0.12	0.12

TABLE II: Numbers of expected and observed events in different mass windows, signal efficiency and upper limit on $\sigma(p\overline{p} \rightarrow G + X) \times B(G \rightarrow e^+e^-)$.

V. CONCLUSION

In 1 fb^{-1} of data collected by the DØ detector at Fermilab we have searched for the lowest excited mode of Randall-Sundrum gravitons decaying to e^+e^- and $\gamma\gamma$ final states. For the coupling parameter $k\sqrt{8\pi}/M_{Planck} = 0.1(0.01)$ we exclude such gravitons with masses $M_1 < 865(240)$ GeV at 95% confidence level.

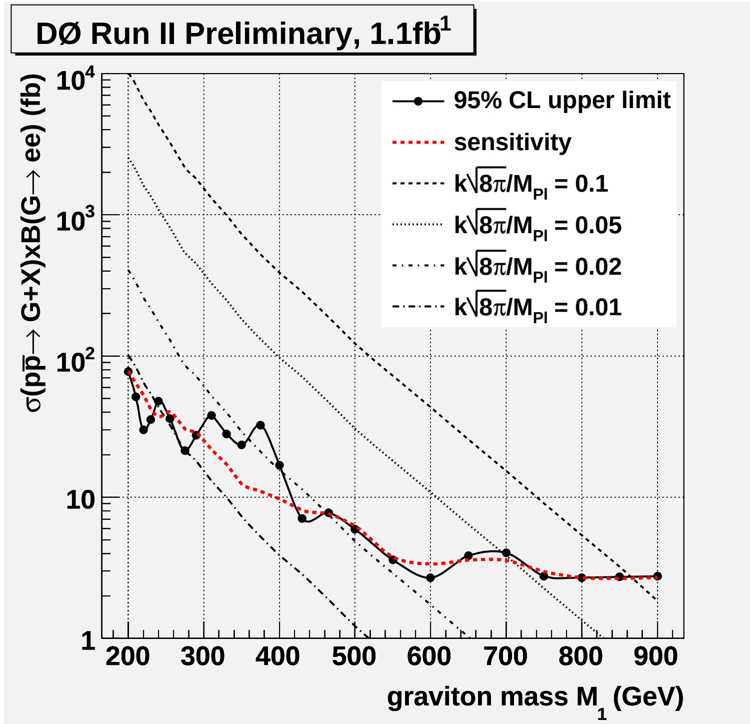

FIG. 3: 95% confidence level upper limit on $\sigma(p\overline{p} \to G + X) \times B(G \to e^+e^-)$ from 1.1 fb^{-1} of data compared with the sensitivity and the theoretical predictions for the two extreme values of $\kappa\sqrt{8\pi}/M_{Planck}$.

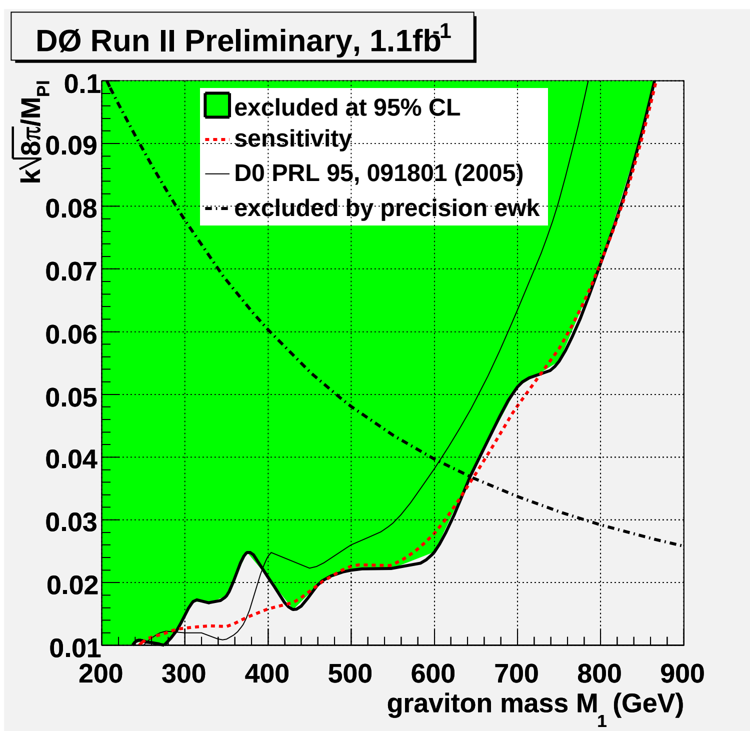

FIG. 4: 95% confidence level upper limit on $\kappa\sqrt{8\pi}/M_{Planck}$ versus graviton mass M_1 from 1.1 fb^{-1} of data compared with the sensitivity and the previously published exclusion contour[2].

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